for a half hour, or an hour, may succeed the breeze. Between 8:30 and 10:30 p. m., and usually between 9 and 9:30, p. m., the breeze begins from the east, being at first but a quiet movement, just observable to the moistened finger. The breeze increases as the night advances, and usually reaches a maximum about 4 a. m. From that hour until the west wind sets in, the movement decreases and there may be a calm.

The wind has been observed during July, August, and September, but it is of more frequent occurrence in the dry season, which this year ended on July 21. From July 9 to July 21, 1901, the wind change occurred daily, with the exception of three days, during the passage of a slight low pressure area. During the remainder of July and the first part of August rains occurred almost daily, and the normal winds were disturbed, especially in the daytime. The night wind occurred on nearly every fair night, but the day wind frequently blew from the south or southwest rather than west, and usually changed to east before a shower.

Mountain and valley breezes are frequent in the mountain valleys of steep grade in the Western States, and, as noted by Mill (Realm of Nature, p. 128), campers and cowboys build their fires so as to have them to leeward of camp when the wind sets in; but it is believed that mountain and valley breezes on such a faint gradient as that noted above have not been often recognized and described.

ORIGINAL MEMOIRS ON THE GENERAL CIRCULATION OF THE ATMOSPHERE.[1]

Compiled and annotated by MARCEL BRILLOUIN, Paris, 1900. Historical introduction translated by the Editor.

INTRODUCTION.

Ever since the first expedition of Christopher Columbus, navigators have known that permanent east winds prevail on both sides of the equator. Emanating from near the Tropics, these winds move first toward the equator and turn more and more toward the west. A rainy zone of equatorial calms separates the two belts of trade winds. Beyond the trade winds and nearer to the poles the west winds blow with much less regularity. Sailing vessels make use of these west winds for the return voyage from America to Europe in the same way that they have utilized the trades to go from Europe to America. Such are the facts as they were generally known when, in 1686, there appeared in the Philosophical Transactions of London a memoir by the astronomer Halley, who had himself sailed through the Tropics and collected numerous observations on the trade winds and the monsoons. In place of the ridiculous explanations which had appeared in the preceding years in these Transactions, Edmund Halley introduced the expansion of the atmosphere under the influence of solar radiation. The air should flow downward toward the warmest point, expand under the action of the sun, and, rising again, spread itself out in every direction. But this, which explains the movement of the air from the poles toward the equator, would require west winds in the morning alternating with east winds in the evening, instead of permanent east winds. It was not the trade winds, but only their diurnal variations, that were explained by Halley; it was a play on words that attributed to the progress of the maximum temperature from east to west, in the train of the sun, the power to carry the movement of the air along in the same direction. In these ideas the apparent motion of the sun was alone considered; the true rotation of the earth had no rôle attributed to it.

Nearly fifty years passed by before, in 1735, this latter influence was recognized by another English astronomer, George Hadley (the brother of John Hadley, the inventor of the sextant), in a memoir entitled: "Concerning the cause of the general trade winds." The air coming from the temperate regions toward the warm equatorial zone arrives at parallels which are farther and farther from the earth's axis of rotation, and whose linear velocity from west to east is greater and greater; the air therefore remains behind. This retardation is really much less than the 87 miles an hour that the change of latitude from the Tropics to the equator would seem to indicate, because all along its course the air is partially carried forward by the surface of the earth over which it flows. Moreover,

> * * * the northeast and southeast winds which prevail between the Tropics must be compensated somewhere by northwest and southwest winds, and generally the winds from any quadrant whatever must be compensated by opposite winds elsewhere; unless this were the case the rotation of the earth on its axis would not be maintained.

The air that has risen above the equatorial zone has maintained a velocity from west to east nearly equal to that of the equator itself; it overflows above the air of the trade winds, redescends toward the poles and appears beyond the Tropics as a west wind; but Hadley does not explain the meridional component of these west winds. Although the influence of the motion of the earth is not correctly estimated, yet this memoir is fundamental; it remained, however, unknown for nearly a century.

Hurricanes or cyclones alone attracted the attention of meteorologists during the first half of the nineteenth century. Nevertheless, in 1825, Leopold de Buch expressed the opinion that the counter trade winds descend to the surface of the earth toward the Tropics, and flow toward the poles; but if this be the case, how is the circuit completed, and how are the trade winds fed? He does not even ask himself these questions.

In 1855, in the Physical Geography of the Ocean, Maury gave the first Schematic chart showing the circulation of the air on a uniform earth. Maury assumed, without, however, giving reasons satisfactory even to himself, a singular intercrossing of currents at the poles, the Tropics, and the equator.

The following year, 1856, his compatriot, Ferrel, at Nashville, Tenn., not being satisfied with Maury's book, published in an American medical journal, an entirely different drawing. According to him the atmosphere is subdivided into six zones of independent circulation, separated by belts of motion alternately ascending at the equator and along the polar circles, and descending along the Tropics and at the poles. A minimum pressure prevails at the equator and in the polar regions; a maximum pressure prevails on the twenty-eighth degree of latitude.

This memoir by Ferrel was soon followed by a purely mathematical memoir on the motion relative to the surface of the globe. The equations adopted in this memoir are the strict equations of relative motion; the centrifugal accelerations are introduced into it in a natural and complete manner as a consequence of the passage from fixed coordinates to coordinates moving with the earth. Ferrel showed the

[1]Professor Marcel Brillouin, of Paris, has lately published a French translation or summary of a number of important meteorological memoirs under the general title of Mémoires Originaux sur la Circulation Générale de l'Atmosphère. He has enriched this volume with numerous notes—historical, explanatory, and critical—so that it forms an important and convenient introduction to the study of the hydrodynamic problems that are presented by the earth's atmosphere. It is also the best introduction to Brillouin's famous memoir of 1898, entitled Vents contigus et Nuages. The introduction to this volume consists of an interesting historical memoir by Brillouin, which we take the liberty of publishing in full in the accompanying translation, believing that the readers of the MONTHLY WEATHER REVIEW will profit by Brillouin's criticisms and will not be misled by one or two passages, in which he gives the views of de Tastes as to the importance of the Gulf Stream and the Kuroshiwo rather more prominence than would seem necessary in the present state of our knowledge.

preponderating rôle of the horizontal components of the centrifugal acceleration due to the horizontal movements of the air; one of these only, the one perpendicular to the meridian, had already been introduced by Hadley; the other, the meridional component, is no less important. Reasoning first upon an atmosphere that is not subject to any resistance either from internal friction or from the action of the earth, Ferrel showed that the free surface would be depressed at the equator, inflated at the Tropics, and would descend again to the level of the earth near the polar circles; the polar cap would be entirely devoid of atmosphere. However extensive the modifications due to the resistances may be, they can not entirely destroy these characteristics; the depressions of the poles and of the equator must exist in the true atmosphere, and the two zones of maximum pressure must exist near the Tropics. Not being able to introduce into a rigorous demonstration resistances, of whose mathematical laws we are ignorant, Ferrel continued his study of the true atmosphere, explaining in a generally plausible manner the mode of action of these resistances and the disturbances that may be produced by them. He showed finally that these resistances must play only a very small part in the equation which unites velocity of the wind from east to west with the variation of pressure along the meridian; it is by means of this equation that Ferrel computed the velocities of the wind and draws his diagrams, taking as his point of departure the mean distribution of the pressure observed at sea level and its variation with height, according to Laplace's formula.

One can not too much admire this collection of memoirs by Ferrel; by the closeness of his reasoning, whenever it is possible, and the delicacy of his perceptions, the student of Nashville is the worthy predecessor of von Helmholtz.

At the same epoch and in an independent manner James Thomson, profiting by an idea expressed by Murphy (1856) as to the cause of the polar depression, proposed a simpler representation at the meeting of the British Association at Dublin (1857). Only an extract then appeared, the figure shown in 1857 not being published until 1892 in the Bakerian lecture given by James Thomson, "On the grand currents of atmospheric circulation," a few months before his death. Without changing his theoretical point of view, but making more and more use of the results of observation, Ferrel published in 1860, and again in 1890, two diagrams sensibly differing from the first.

It is to be remarked that there is no modification of Hadley's point of view; without solar action the atmosphere would be in a state of repose. The action of the sun sets it in circulation along the meridians; the rotation of the earth changes this motion. The parallel of relative quiescence is determined by the condition that the total action of the atmosphere upon the earth should be *nul*. This is very nearly the same point of view as that which predominates in subsequent works; but the rotation takes the first place.

In 1886 W. Siemens published a theory which rests upon a very questionable principle: If the atmosphere were carried along by the earth without any relative motion, this entrainment would give it a large living force of rotation. Let us now suppose that the atmosphere were thoroughly mixed: Siemens admits that as a consequence of the mixture a uniform distribution of the linear velocity in the whole mass would result; he admits, furthermore, the conservation of the living force of the whole. On these conditions the general linear velocity would be 379 meters per second, or the same as the velocity of the earth at latitude 35° 16′. On the interior of a cylinder having this parallel for a base the entire depth of an atmosphere of uniform temperature would be occupied by west winds, with east winds on the outside. The inequalities of temperature produce a meridional circulation which combines with the preceding.

This memoir by Siemens is not perfectly clear, but as it marks his return to the study of the general circulation after thirty years of indifference, it seems useful to translate it in full.

The following year, 1887, Mr. Möller published a work of much closer analysis, but of a mixed character, analogous to that of Ferrel's works, in the sense that he borrows some of his results from observation. Although in the memoir itself it is often difficult to see to what extent the theoretical deductions are guided by a knowledge of the true circulation, several passages have a real interest, particularly the analysis of the part played by the resistance that the ground opposes to the motion of the air.

A discussion, which the vague character of Siemens' views contributed to render somewhat confused, was carried on for several years between Siemens, Möller, Sprung, and Oberbeck in the Meteorologische Zeitschrift; it does not, however, seem to me necessary to extract anything from it.

A little later Oberbeck (Acad. des Sciences, Berlin, 1888), adopting the simplest distribution of temperatures with latitude capable of producing a maximum at the equator and a minimum at the poles, i. e.,

$$T = \left(Ar^2 + \frac{A'}{r^3}\right)(1 - 3\cos^2\theta),$$

where T = temperature; θ = latitude; r = radius to earth's center; A, A' = constants, and seeking to take into account the internal friction of the air, but neglecting its compressibility, obtained the following results:

On account of the difference of temperature, the air rises between the equator and latitude 32° 16′, and descends from thence to the poles. The velocity of the descent at the pole is double the velocity of ascent at the equator. The horizontal meridional velocity, zero at the pole and at the equator, attains its maximum at a latitude of 45°. The vertical velocities, zero at the surface of the earth, are everywhere very small in comparison with the horizontal velocities.

The motion along the parallels of latitude due to the reaction of the rotation of the earth upon the thermal circulation, is superposed upon two others: (1) A current flowing toward the west which prevails between the equator and latitude 35° 16′; beyond this latter the current flows toward the east; it is annulled at the poles (as a consequence of the friction). (2) A current flowing toward the east which is zero at the surface of the earth, zero at the equatorial plane, and zero at the poles, but increases very rapidly with altitude and has a maximum at latitude 54° 44′.

From the combination of these three movements (meridional, rotational, and vertical,) there results as the trajectory an open curve, the concavity of which, for movement in the lower strata, is open toward the west, but for the upper strata, toward the east; as its velocity north and eastward is much greater than it is at the surface of the earth, the upper branch of the trajectory crosses the lower branch at about latitude 54°. In the absence of determinations of the coefficient of friction of the air, Oberbeck did not seek in this first memoir to deduce the velocity of the wind from the observed temperatures. Several months later, changing his point of view a little and correcting a rather important theoretical lapsus, Oberbeck determined the velocities produced in the Southern Hemisphere by the mean observed distribution of the pressures, according to his theory, supposing the influence of the inequalities of temperature upon the pressure to be negligible. He thus found a west wind between the pole and latitude 16° 49′, whose maximum velocity is 4.59 meters per second at latitude 56° 27′. Between 16° 49′ and the equator the wind blows from the east, with a maximum velocity of 13.5 meters at the equator, in place of the equatorial calms. This is a computation analogous to that of Ferrel, but under a different analytical form.

Siemens and Oberbeck, as we see, return to the circulation over a whole hemisphere, which Ferrel had seemed to wish to abandon in the beginning of his works. Under these conditions, in order to avoid the extreme velocities that the principle of the conservation of areas seems to impose, it is indispensable to introduce the resistances. Oberbeck has imposed upon himself well-chosen limiting conditions: at the lower surface, entrainment by the terrestrial globe, which is not far from the truth in the permanent condition; at the upper surface, although but a little distance from the surface of the earth, a total absence of vertical movements. But, in order to take into account the internal viscosity of fluids, he has adopted equations of the same form as those for small, slow motions, with a resistance in proportion to the velocity of deformation, reserving the right to adopt a value of the coefficient of friction certainly very different from that of the laboratory experiments.

Unfortunately, this resistance, which is a linear function of the relative velocities, is for rapid and general motions, not in accordance with the facts. It is well known that the mechanism of the resistances in the rapid motions of great fluid masses is not the same as that of the slow motions of the laboratory; it is the square of the relative velocities that must be considered, and not the relative velocities themselves.

It is to Helmholtz, who had already done so much to explain the boundary conditions in hydrodynamics and hydraulics, that we owe the introduction of true ideas as to the motions of an atmosphere at the surface of a revolving globe.

In his first memoir on the motions of the atmosphere (Sitz. Ber. kön. Pr. Akad. Berlin, 1888), Helmholtz shows the inadequacy and the slowness of the action of the internal viscosity and of the conductivity of gases. He afterwards establishes, by an analytical method, the characteristics of the distribution of pressure in a mass of dry air in convective equilibrium, with rotation, and deduces from this the inclination and the condition of stability of the separating surfaces of two separate annular masses of air. In the normal case, "which experiences only local exceptions under special conditions," the temperature and the radius of calm[2] diminish together from the equator to the poles. The surface of separation rises, therefore, toward the polar side, but remains included between the pole and the horizon. Near the equator it grazes the horizon. The atmosphere is thus formed of an infinite number of layers, in which the velocity and the temperature vary continuously. The warming of the air below or its cooling above produces an active vertical circulation, which mixes together the various layers of the atmosphere and puts them in convectional equilibrium. The heating above or the cooling below, on the contrary, leaves the layers intact.

The resistance of the ground retards the west winds and displaces the air forming them toward the pole as long as it remains at the surface of the earth, then forces it to rise. On the other hand, the resistance of the earth accelerates the east winds and pushes them toward the higher parallels, close to the ground. It is only within the equatorial circle itself that the east winds leave the surface and rise in the plane of the equator itself up to the extreme limits of the atmosphere.

At the surface of stable separation of two contiguous rings of different velocities, billows should originate which, for a certain length of wave, will constitute a more stable form than that of the uniform surface of revolution. These billows, spreading themselves perpendicularly to the meridians, may increase and break up into whirls or rolls and give rise to whirlwinds and cyclones. According to a modified paragraph, in a second memoir, Helmholtz states, that, in consequence of the low temperature at the poles the air flows down close to the ground under the form of east wind or anticyclone; above, the warm layers flow toward the pole to fill up the vacuum and continue their course as west wind or cyclones.

Broken up by the irregularities of the surface of the ground the anticyclonic movement of the lower strata, and the vast cyclone gradually increasing in the upper strata, which one should otherwise find at the pole, break up into a great number of irregular, straggling anticyclones and cyclones, the latter predominating.

From these considerations, I conclude that the principal obstacle to the development of winds much more violent than those which we now observe consists less in the friction of the surface of the earth than in the mixture of layers of air animated by different motions due to whirls formed by the rolling up of the surfaces of discontinuity. In the interior of these whirls the layers of air originally separated are rolled one around the other into more and more numerous and thinner layers; the enormous extent of the surfaces of contact makes possible a rapid exchange of temperature and an equalization of the motion by friction.

In his second memoir (1889) Helmholtz shows that, in the case of dry air, in a condition of stability and with decreasing temperature from the equator to the poles the mixture forms an ascending ring [around the globe] between the two rings [or zones] whence it proceeds. In the two neighboring rings the air at the bottom is thus pushed toward the surface of separation where the difference of the velocities increases.

Easterly winds may even occasionally blow from the polar side. On account of the numerous local disturbances in the great atmospheric currents, no continuous line of separation will, as a general rule, form; it will be broken up into separate parts which will appear as cyclones.

Thus, continuity should exist in the upper regions of the atmosphere; it is below that we must seek for the origin of the breaking waves and billows. These latter show themselves only when the lower air is saturated to its utmost capacity; each wave crest then appears like a cloud; the sky is covered with bands of parallel cirrus clouds. When the surface of separation is only a short distance above the ground the passage of each cloud is manifested by a gust of wind.

In the rest of the memoir of 1889 and in the memoir of 1890 Helmholtz occupies himself only with the formation of the waves in the atmosphere and the conditions for forming breakers or foamers. It is a difficult mathematical theory in point of detail, interesting without doubt, but only a side issue from the point of view of general meteorology. The essential instability is, as I believe I have shown elsewhere (Marcel Brillouin, Vents contigus et nuages. Ann. du Bur. Cent. Met., 1898), produced by the variations of temperature and cloudiness upon a surface originally stable and is not that which results from the waves.

Up to the present time I have only spoken of foreign memoirs. I would mention only one purely theoretical French memoir on the general circulation, viz., the one published by myself "Vents contigus et Nuages" in the Annales du Bureau Central Météorologique, 1898. In this memoir I tried to point out the modifications that the presence of the clouds or of aqueous vapor introduces into some of von Helmholtz's conclusions, and I principally directed my efforts upon the study of the forms of clouds produced by the mixtures.

I have systematically omitted all the memoirs, foreign as well as French, which deal with "the trajectories of inertia at the surface of the earth." It would simplify the problem too much to suppress the moving forces due to the inequalities of pressure and to compare the motions of a mass of air with those of a material heavy point.

In order to enable the reader to judge of the scientific value of the memoirs contained in this volume and to appreciate their influence upon the progress of general meteorology, it seems to me necessary to give here a glance at the

[2] That is, the calm layer, or the surface of separation between the two moving layers.—ED.

point adopted by those French meteorologists who have interested themselves in the general circulation of the atmosphere; it will thus be less difficult for us to form our conclusions.

It is Mr. Maurice de Tastes who, in his various notes to the Comptes Rendus from 1867, and in his memoir on the Theory of Atmospheric Circulation[3], inaugurated a new manner of regarding the general circulation of the air by adopting as a basis to construct his theory the earth and the oceans as they are described to us in geography, instead of the fictitious, uniform earth which is the object of purely speculative theory only.

Starting from a certain number of well established facts, such as the existence of the regular winds, the trade winds, the monsoons, and the ocean currents, the distribution of temperate or extreme climates, their relation with the division into continents and oceans, and with what we know of the hydrodynamics of elastic fluids, why should we not rush boldly forward with our hypothesis and imagine a system of atmospheric circulation which takes account of known facts. This system once established, let us see whether the later facts revealed to us by subsequent observations will confirm the hypothesis or tend to modify it.

Struck with the excessive importance attributed to the vertical motions of the air which "in the totality of the atmospheric motions are negligible in comparison with translatory motions parallel to the surface of the globe," M. de Tastes is led, in a first sketch, to consider only the motions tangential to the surface of the globe and to neglect the motions in the normal direction which are of importance only in local meteorology.

This aerial film covers a heterogeneous surface, formed on the one hand by the oceans, whose specific heats are considerable, and whose emissive and absorbing powers are very feeble; on the other hand, by continents whose surfaces have much smaller specific heats and emissive powers more or less energetic.

The diathermic air is warmed only by its contact with the surface of the globe; it is warm and dilated between the Tropics, cold and condensed at the poles, whence arise the double motion, in consequence of which the cold air coming from the pole and the warm air coming from the equator, "should, in the temperate latitudes, attain nearly the same density, and form contrary currents, no longer superposed but in juxtaposition."

The rotation of the earth, and the distribution of the warm marine currents, determine the position of the aerial currents. The air which reposes upon the warm waters of the Gulf Stream, and which is maintained at a high temperature by contact therewith constitutes a long trail of warm, dilated gas which facilitates the translatory motion of the equatorial air toward the polar region, and to a certain extent serves to stimulate it. The oceanic Gulf Stream determines the formation of a veritable aerial Gulf Stream, which—

After having approached our western coasts continues its course eastward across the north of Europe where the vapors, of which it is composed, are condensed either as rain or snow; it irrigates Sweden and Finland and returns across eastern Europe in the form of a dry, cold wind. In proportion as it approaches the equator it is heated and becoming northeasterly in southern Africa it contributes to the sterility of the deserts which it traverses and reappears upon the west coast of Africa and thus completes a vast circuit, a sort of aerial river, which surrounds a region of relatively calm air.

Zone of calm with high pressures; low pressures in the current "because the air there is in motion;" slow undulations of this current ending sometimes, but rarely, in the formation of violent vortices on the left side of the current which, in our hemisphere, is the most rapid side; such are the principal consequences of this condition of things.

All the vicissitudes of our climates depend upon the oscillations performed by this zone of calms and the aerial current surrounding it about their normal location; and it is upon the careful observation of these changes that the solution of the great problem of weather predictions depends, which has always been the principal object of the efforts of meteorologists.

An analogous circuit, more extended but more fluctuating on account of the smaller force of the Kuroshiwo, passes to Japan and returns across North America.

The descending branch of the Pacific circuit, and the ascending branch of the Atlantic circuit, are quite near to each other, and are animated by opposing velocities. They are liable in their respective fluctuations to come into contact and to realize conditions favorable to the formation of the terrible cyclones which infest the coasts of the Antilles, of Florida, etc. The invariable direction of the gyratory motion of these storms is precisely that which would result from the joint rotation produced by two currents in juxtaposition, and propelled by opposing velocities; this confirms the hypothesis which we have accepted as the explanation of gyratory motions.

The north of Asia is outside of these two circuits; there "high pressures and prolonged calms prevail." To the south of its mountain barrier extends the region of the monsoons. In the polar regions, finally, the air has no general motion in any direction.

Without entering into any new details in regard to the Southern Hemisphere, we see quite well how nearly these views approach the reality; the resemblance is improved by the author's remarks as to the rôle of the mountains and the coasts, as to the general movement from north to south, and from south to north during the course of the year, and as to the bifurcations of the currents which enable the two circuits to partially separate at the north in order to surround the polar regions with a continuous current from the west.

If we consider the almost total absence of documents at the time of M. de Tastes's first publications,[4] we can not fail to recognize that he was the first to point out the great importance of the regions of calms and of high pressures and the rôle played by the warm ocean currents in the determination of the aerial currents.[5] Since that time numerous works, both in France and in foreign countries, those in particular of M. Teisserenc de Bort, have completed the study of the regions of high pressure and have shown that the idea of M. de Tastes relates more especially to the winter season. In summer it is no longer the ocean currents which enjoy the high temperatures, but the continental regions. As the part played by the ocean currents is rather conjectured than proved in the memoir of M. de Tastes, his fundamental idea in regard to the beds of the aerial currents has not yet been confirmed. To the areas of high pressure, whose immobility make them recognizable on the charts of means, M. Teisserenc de Bort added as the "great centers of action of the atmosphere" the centers of low pressure; these are only an illusion on the charts of mean values, resulting from the fact that, notwithstanding the fluctuations of their edges, the aerial currents always pass by certain regions, such as the neighborhood of Iceland, where there is no compensation. The charts of means are similar to the daily maps in the regions of high pressure; they differ, however, entirely in the regions of low pressure, and this greatly diminishes our interest in them. In order that this analogy should be maintained in general, it would be necessary to combine together only similar conditions which would constitute types of temperature like those collated by M. Teisserenc de Bort for rigorous winters.

This important idea of the beds of aerial currents was, however, adopted in the lectures of M. Duclaux at the Agricul-

[3] Annales Bureau Centrale de Météorologie de France, Tome IV, 1879, Météorologie Générale, pp. 1–18.

[4] Comptes Rendus, 1865, 1870, 1872, 1874; Soc. Météor., 1874–75; Cong. de Météor., Poitiers, 1874; Congrès International, 1878.

[5] Brillouin apparently refers to the paucity of meteorological memoirs in France. All of these meteorological phenomena had been matters of everyday familiarity in America since the publication of Buchan's isobars in 1869 and the daily maps of the Weather Bureau in 1870. Ferrel's important works attracted no attention in Germany until 1874, and in France at a still later date. They had, however, been mentioned with high appreciation by the present Editor in the circular "On the practical use of daily weather maps," published anonymously by the Chief Signal Officer in April, 1871.—[C. A.

tural Institute, and was eventually very much transformed and completed, as shown by his lectures, published in 1891.[6]

Renouncing the excessive simplification (which, however, was useful in its day) which caused M. de Tastes to look at the total thickness of the atmosphere as being mobile on the whole, M. Duclaux finds in a happy combination of the equatorial circulation of Hadley with the temperate circulation of M. de Tastes, the justification of the rôle of the Gulf Stream in the formation of the horizontal circuit of the temperate regions (Chap. XIX, p. 276). He then defines the manner in which the current encroaches upon the region of high pressure, or "isle of calms" (Chap. XX, p. 310), and, especially, he introduces the explanation (new as well as correct) of those conditions, which are shown on the isobaric charts as X-shaped isobars, and which some meteorologists study only by halves, under the name of V-shaped depressions. This form, which reminds one of the typographic trace of a neck between two mountains, corresponds to the overlapping of two layers of current in the "isle of calms" (page 312). "The presence in the atmosphere of layers of different temperature and animated by different velocities appears to be very common and has been observed in all aeronautic ascensions." It is to these currents halfway up in the atmosphere that are due the hailstorms of spring and the majority of thunderstorms (Chap. XX, pp. 312–322, and Chap. XXII, pp. 353–363). Nothing is clearer and more precise than his descriptions of the various atmospheric conditions, their characteristics and their results.

Finally, I will close by the following remark, which I have insisted upon in my lectures at the Agricultural Institute, as supplementary to those of 1891 to 1896 by M. Duclaux: At the surface of the earth every belt of low pressure is necessarily occupied, not by one current, but by two opposed and contiguous currents. As long as the wind is not very strong, each of these has high pressures on its right in the Northern Hemisphere. Either of these currents, or even both, may be continuous with the areas of high pressures on their borders, or on the other hand be entirely distinct from them. The chart of theoretical atmospheric currents to which this remark refers differs in some interesting particulars from that of M. de Tastes.

The necessity of studying the earth as it really is and not as an ideal uniform globe appears in numerous articles of various degrees of importance published by our naval officers and our French engineers. I will cite a single example:

The Revue Maritime et Coloniale published in 1894 an extensive memoir by M. Duponchel, who does not appear to have been acquainted either with the memoirs of M. de Tastes or with the work of M. Duclaux. M. Duponchel, whose first note on this subject was written in 1889, seems to have arrived independently at views quite similar to those of M. de Tastes, views which he has explained with his usual vigor in a pamphlet of 1892 and in various articles in the Revue des cours scientifiques.

But notwithstanding some ingenious considerations, these memoirs do not add anything to that of M. de Tastes; neither do they add anything to M. Duclaux' work. None of the criticisms of M. Duponchel's views made by naval Lieutenant Tournier[7] apply to the exposition of M. Duclaux.

Without entering into further details, two words will suffice to put the reader on his guard against mixed (theoretical and observational) memoirs.

The influence of the continents and oceans in our Northern Hemisphere—the only one which is well known—is so overwhelming that there is no reason to admit the slightest resemblance between the distribution of pressure and temperature deduced from observations by taking the means by parallels of latitude and the distributions that the same astronomical conditions would produce upon a truly uniform globe. As to the mean wind of the temperate regions—what can it be?

There is, therefore, no reason to attribute a closer relation between scientific facts and the results of those authors who, like Ferrel and Möller, make partial use of these average data, than between the results of those in which a purely theoretical point of view prevails. As regards these latter, we must not judge them from the more or less complete agreement of their results with the said means of observations, but solely according to the rigor of their mechanical and thermodynamic reasoning, and from this point of view no memoir can compare with that by von Helmholtz. He seems to me to have exhausted the subject that he treats of "The circulation of a dry, gaseous atmosphere upon a polished globe, revolving like the earth."

But this is not the last stage; we must find a rigorous treatment of the problem proposed by M. de Tastes, that of the atmospheric circulation upon the earth as it really is—at least in its general features. In attacking this directly, M. de Tastes has been forced to be content with rather vague considerations. To-day the instrument of attack has been forged by von Helmholtz; the principles of the mechanics of the atmosphere, the part played by the mixtures and that played by the resistance of the ground have all been clearly analyzed. It therefore seems that we need only to make known these principles in order to quickly stimulate purely theoretical studies, the comparison of which with observed types—not with averages—may be reasonable. This is the only method of discovering whether all the important elements have really been taken into consideration. It is for these reasons that the publication of the principal theoretical memoirs on the general circulation of the atmosphere at the surface of a uniform globe has seemed to me to be opportune.

CLIMATOLOGICAL DATA FOR JAMAICA.

Through the kindness of Mr. Maxwell Hall, the following data are offered to the MONTHLY WEATHER REVIEW in advance of the publication of the regular monthly weather report for Jamaica:

Jamaica, W. I., climatological data, July, 1901.

	Negril Point Lighthouse.	Morant Point Lighthouse.
Latitude (north)	18° 15′	17° 55′
Longitude (west)	78° 23′	76° 10′
Elevation (feet)	33	8
Mean barometer, 7 a. m.	29.901	29.901
Mean barometer, 3 p. m.	29.878	29.870
Mean temperature, 7 a. m.	79.2	....
Mean temperature, 3 p. m.	84.1	....
Mean of maxima	87.6	....
Mean of minima	74.2	....
Highest maximum	92.0	....
Lowest minimum	72.0	....
Mean dew-point, 7 a. m.	74.2	....
Mean dew-point, 3 p. m.	76.2	....
Mean relative humidity, 7 a. m.	84.0	....
Mean relative humidity, 3 p. m.	77.0	....
Total rainfall (inches)	3.16	4.44
Average wind direction, 7 a. m.	var.	var.
Average wind direction, 3 p. m.	var.	var.
Average hourly velocity, miles, 7 a. m.	7.5	8.2
Average hourly velocity, miles, 3 p. m.	11.6	11.9
Average cloudiness (tenths):		
7 a. m. Lower clouds	0.1	2.2
7 a. m. Middle clouds	1.6	1.8
7 a. m. Upper clouds	4.4	1.0
3 p. m. Lower clouds	2.7	1.8
3 p. m. Middle clouds	5.3	2.0
3 p. m. Upper clouds	0.7	1.2

NOTE.—The pressures are reduced to standard temperature and gravity, to the Kew standard, and to mean sea level. The thermometers are exposed in Stevenson screens.

[6] Cours de physique et de Météorologie professé à l'Institut agronomique. Hermann, 8 rue de la Sorbonne, Paris.

[7] Revue marit. et colon., October, 1894.